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An automatic Tarif for news film

D.T. Wright, C.Eng., M.I.E.E.

Research Department, Engineering Division
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Summary

This report describes equipment which will make automatic frame-by-frame corrections of lift, colour balance and gain errors in the red, green and blue colour-separation signals of a colour television system. The principles of correction are; set the blackest part of each colour-separation signal to a common preset reference level, make the mean levels of the three separation signals equal, and hold the maximum luminance value of the output signals at a fixed magnitude.

Although these corrections may not produce results which are as good as can be obtained by a trained operator, considerable advantage is gained by the very rapid change of correction when a new shot occurs. Field trials have shown that the automatic unit, followed by a conventional manual Tarif unit, can improve operational performance.

Issued under the authority of

P. Rainger

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

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1. Introduction

Manual Tarif Tarif units which are operated manually have been used in colour television broadcasting for several years.[1] Such a unit is usually placed at the output of a telecine channel to provide controls with which an operator can vary certain parameters of the red, green and blue colour-separation signals. A Tarif unit enables adjustments of 'master-gain' and 'master-lift' to be made, together with selective adjustments of gain and black-stretch in each of the three colour-separation channels. The selective controls allow correction of the colour of highlight and shadow areas respectively; in some cases selective lift-control is provided instead of, or in addition to, selective black-stretch control.

In a film sequence it is often necessary to re-adjust the Tarif settings for each new shot. When the differences between the required settings for each shot are small, and the operator has had time to rehearse the sequence, the optimum settings can be arrived at very soon after the start of each new shot and the viewer does not notice that the correction is being adjusted. If, however, a shot has suffered from a serious error, say of colour-balance, and the operator has not had sufficient time to rehearse the required settings, it will take longer than normal to re-adjust the Tarif. The combined effect of a large error for a period longer than usual makes the correction process clearly noticeable to the viewer. Further, when such a shot ends it is likely that there will be some delay before the large degree of correction is removed, and the viewer will see this as a second disturbance.

Pre-Programmed Tarif If the transient effects at a shot-change are not to be seen by the viewer, the corrections must be changed very rapidly and preferably during the scanning of the first film frame of a new shot. The ideal way of doing this is to use a pre-programmed Tarif.[2] This is an arrangement in which the Tarif settings for each shot are recorded on punched paper-tape together with the number of the film frame at which the shot starts. Rehearsal is required to determine the optimum settings, and to note the frame number at which each shot change occurs; the latter may be found with the aid of an electronic shot-change detector.[3]

Automatic Tarif In news film operations the rehearsal procedure required for a pre-programmed Tarif is not practicable, and film is sometimes transmitted completely unrehearsed. In addition, the shot-to-shot variations of film colour-balance are often quite large.

If fixed rules can be applied which determine how corrections are to be made, it becomes possible to apply such corrections automatically, on a field-by-field basis. This will produce an output signal corrected according to the rules after only a single field period has elapsed; this is the principle of automatic Tarif. In practice, a compromise must be made since no fixed set of rules can always provide optimum correction. However, preliminary experimental work[4] using the processing channels of a flying-spot film-scanner has shown that a considerable subjective improvement in picture-quality can be obtained if an approximate correction is applied immediately after each change of shot.

The device which is the subject of this report was developed in order to carry out comprehensive field trials. It has been designed so that it can be used as an add-on unit at the output of a telecine channel, or any other source that produces colour-separation signals having associated synchronising and blanking signals. It was envisaged that the automatically corrected signals could, if required, be fed to a manual Tarif enabling an operator to make any necessary small trimming adjustments.

2. The correction rules

The automatic Tarif incorporates three controlling functions which influence the lift and gain settings of the three colour-separation signals. One function involves a selective control of lift, another is associated with selective gain controls for colour-balance correction and the third function provides overall gain control to maintain the output-level constant. Each function operates as described in the ensuing sub-sections, and the automatic adjustments are made in the order in which they are listed.

2.1. Black-level correction

That part of each colour-separation signal nearest to black-level (excluding the blanking intervals) is set to a common reference level[5] (say 5% of white level) by the automatic application of independent lift control voltages. This operation is intended to remove colour casts from low-light and shadow areas.

2.2. Colour-balance correction — 'integrate to grey'

The mean levels of the three colour-separation signals (averaged over each field period) are made equal by using one channel as a master and controlling the gains of the other two channels; this produces a picture which integrates to grey. Earlier work[4] had shown this operation effectively removes colour casts in mid-tone and highlight areas.

2.3. Gain correction

The output 'peak luminance' level (a weighted sum of the individually measured peaks of the red, green and blue output signals) is made, by means of an overall gain control, equal either to a preset reference level (say 0·7V), or to the largest peak value of the three colour-separation signals at the corrector input. Automatic gain correction is necessary to compensate for the action of the black-level and colour-

balance corrections whether or not there are any overall gain errors in the input signal. The use of the largest peak value of the input signals as the overall output reference level allows compensation for the action of the black-level and colour-balance corrections, whilst maintaining any intentional gain errors present in the telecine signals, such as occur in fades to or from black. Its use is described more fully in Section 3.3.

3. Controls

3.1. Modes of operation

Originally an on-off switch was provided for each of the three correction functions described above, but after early field trials it became apparent that only three of the eight possible combinations were required. It was also realised that, if any worthwhile assessment of the value of the unit was to be made, remote selection of these three combinations from the telecine operating desk was essential. (The unit cannot be placed near the operating desk because colour-separation signals are not available there.)

The three modes of operation, which can now be selected remotely, are as follows:—

A No correction
B Black-level and gain correction
C Black-level, gain and colour-balance correction

In all cases the output signals are subject to black- and white-level clipping.

3.2. Rate of correction

When film is scanned to produce television pictures two fields are produced from each film frame. In terms of colour content these two fields may be considered identical. Corrections may be applied during the vertical blanking interval either after every television field, or only after each odd field or each even field. The choice depends largely upon the type of signal source with which the automatic Tarif is to be used.

Each new correction condition is determined by measuring the immediately preceding field. In this way, if consecutive frames in a film sequence are identical, the correction is appropriate after the first full field of the sequence. Even with large amounts of movement in the scene, successive frames are usually sufficiently alike for no visible errors to be caused by a one-field delay in the correction process.

Correction on alternate fields is intended for use with twin-lens flying-spot film scanners. With this type of film scanner, the odd and even fields are scanned using different lenses whose transmission characteristics may differ, and, as a result, 25 Hz flicker is often present on the output signals. If automatic gain-correction were applied after every television field, then a field with high output level would cause a gain reduction for the following field which is already of low level and vice versa; the net result is that the original flicker would be doubled.

When new settings are derived from alternate fields, the delay between a shot-change and the situation where the correction is appropriate to the new scene can be up to two fields. However, with twin-lens machines whose output video signals are picture-phased, the first television field corresponding to each film frame will always be, say, an even field. It is thus simple to arrange that this first field is used for measurement and that the correction is applied in the vertical interval before the second (interlaced) field. When correctly phased with the film in this way, alternate-field correction will always be delayed by only one field period and thus it has no disadvantage over correction on every field.

Camera-tube telecines cannot normally be picture-phased and unless 25 Hz flicker proves troublesome it would seem preferable to correct at field-rate rather than involve unnecessary delay in the correction process.

3.3. Output parameters

A front panel control, the output lift control, is provided to adjust the reference level to which the blackest part of each colour-separation signal is set (see Section 2.1.). In this way the lift level of the output signals can be preset to suit particular operational preferences, typically between 2% and 7% of peak signal magnitude. The control is only operative when the black-level correction is in use.

An output reference selector is provided in the form of a switch to select, as the gain-control reference, either a fixed reference potential or a voltage corresponding to the highest peak value of the three telecine signals.

The fixed reference is intended for use with telecine signals that have large unwanted shot-to-shot variations in peak magnitude, such as would be produced by a flying-spot telecine when scanning film of verying exposure. The reference level is normally set to give a 'peak luminance' output of 0·7V and this will be maintained for wide variations in input level.

When the telecine signals have already been controlled in gain, such as in a camera-tube telecine with a light-valve control, it is preferable to use the highest peak of the three signals as the output reference. With this system, as the telecine signals fall in level, the output is allowed to fall in sympathy and the device has an effective overall gain of unity. In this way it does not interfere with any purpose-designed response of the light valve or any intentional fade to black. The device is still effective however in removing any changes to the overall gain which the colour-balance or black-level corrections would otherwise cause. For example, if the red-channel gain were increased to achieve the correct colour balance then, without such gain correction, the 'peak-luminance' value of the output would also rise.

When the telecine has an automatic light valve the use of a fixed output reference can have the following disadvantages:

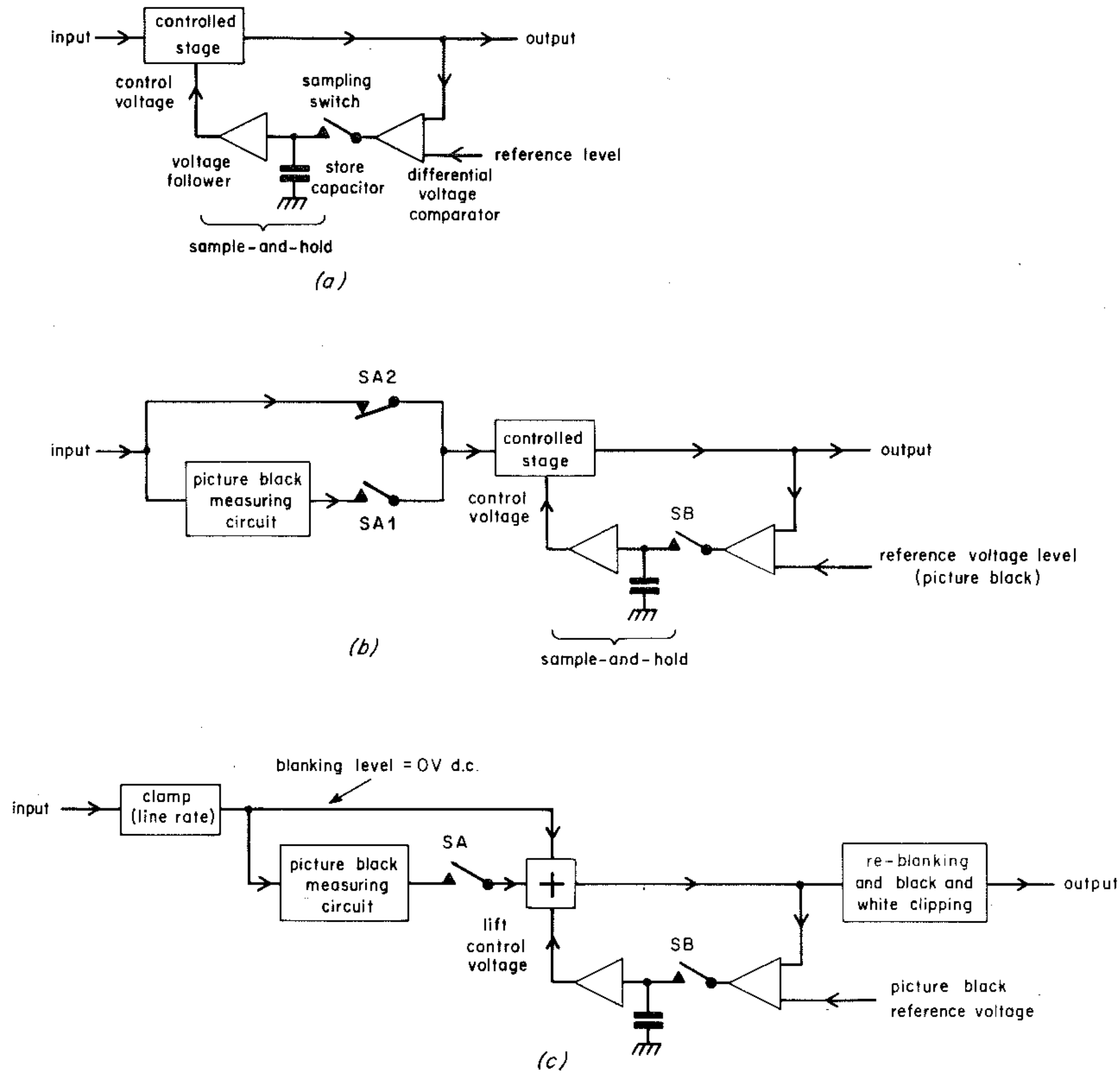

Fig. 1

(*a*) Basic control-loop (*b*) Modification of (*a*) to achieve black-level correction (*c*) Practical version of (*b*)

1. Because the automatic Tarif has a rapid response it will over-ride the 'slow up, fast down' gain-control characteristic of a light valve.

2. Black film-leaders or intentional fades to black cause a large increase in gain which is noticeable because of the attendant increase in noise level; (an increase in light level caused by the light valve does not affect the noise level).

3. The first field after a black leader is subject to very high gain owing to the combined effects of the light valve and the automatic Tarif, neither of which can respond sufficiently quickly to the new signal level. It thus appears at a level where almost the entire field is white-clipped.

4. Any flicker at half the correction rate of the automatic Tarif, such as may be caused by the film or the telecine mechanism, or by hunting of the light valve, is doubled in excursion by the automatic correction.

None of these effects are serious in practice, but all are avoided by using the highest peak value of the three telecine signals to provide the output level reference.

4. Instrumentation

4.1. Control loops

The basic type of control-loop used in the equipment is similar to that of a feedback clamp. Extensive use is made of field-effect transistors as electronic switches for signal switching and sample-and-hold applications. The most basic form of control-loop shown in Fig. 1(*a*) could

perform for example, as a clamp operating, not on every back porch interval (at line rate), but on a single blank line in each field interval. During such a line, the comparator output represents the amplified error between the actual output blanking-level and the required level as defined by the reference voltage. If the sampling switch of the sample-and-hold circuit is closed at this time the output of the differential-comparator can change the voltage on the store capacitor and hence the control-voltage. In this instance the controlled stage may simply be an adder which adds the control-voltage to the input signal; the phasing of the control-voltage is arranged so that it tends to reduce the error at the output. After sufficient time has been allowed for the error to be reduced to zero, the sample switch is opened and the value of the control-voltage is held constant by the store capacitor during the next field. In this way the output signal when the switch is closed (in this case blanking-level) is made equal to the reference level.

The above system can only set the blanking-level of the input signal to a fixed reference-level at the output. However if, at the time the sampling switch is to be closed, the input signal is replaced by another voltage which corresponds to the blackest part of the picture information during the previous field, then the corresponding output will be made equal to the reference level. Fig. 1(*b*) shows how this can be achieved. The voltage level which corresponds to the blackest part of the picture is obtained by measuring the peak negative ('black-going') excursion of the input signal over a whole field, having first gated out the blanking intervals; (details are given in Section 4.3.). The result is stored until the field interval occurs and then switches SA1 and SA2 substitute this measured voltage level for the input signal. This stored measurement is thus carried as a pulse (a signal-measurement-pulse) on the normal video signal during the field interval, i.e. when, normally, no other video information is present. It is then possible to achieve the required output conditions by controlling the insertion of new blanking pulses using the pulse as a reference. Switches SA1 and SA2 are arranged to operate from just before until just after the operating interval of the sampling switch SB. This allows the voltage-comparator output to settle to the level of the signal-measurement-pulse before the feedback-loop is closed. If the signal corresponding to the blackest part of a new field is the same as that for the previous field it will also be equal to the value of the signal-measurement-pulse derived during the previous field. Since this pulse was used to set the output blanking-level, the new field will have the correct black-level at the output.

In order that the picture black-level measuring circuit (which measures over a whole field) can produce a meaningful result, a clamped input-amplifier is required to establish the d.c. level of the input signal. If the input clamp is arranged to set the blanking-level to zero volts, then switch SA2 becomes redundant since, at the time it disconnects the input signal, the signal already has a blanking-level corresponding to zero volts. (This assumes that the input signal has a cleanly-blanked field interval.)

The final arrangement for black-level control is shown in Fig. 1(*c*). The output from switch SA is now added to the input signal and since, for black-level correction, the control-voltage is also added to the input signal, one adder is used for all three signals.

The whole circuit is d.c. coupled and, in order to modify the signal to the corrected black-level, the output signal must be re-blanked. It is also necessary to use black-level and white-level clippers on the output signal because the corrected signal may contain high frequency components which go below the new blanking-level or above white-level. The output blanking also serves to remove the signal-measurement-pulses from the video information.

If the picture-black measuring arrangement incorporated in the circuits of Figs. 1(*b*) or 1(*c*) is replaced by one which measures the peak signal level, and a variable-gain amplifier is used as the controlled stage, a gain-correc-

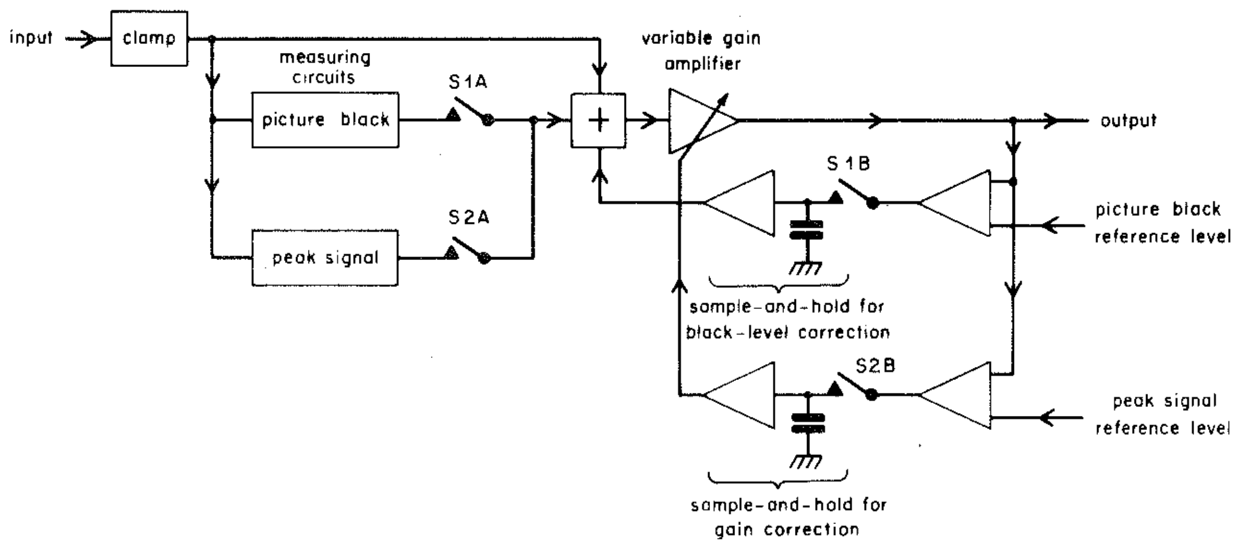

Fig. 2 - Combination of black-level and gain correction around a common signal path

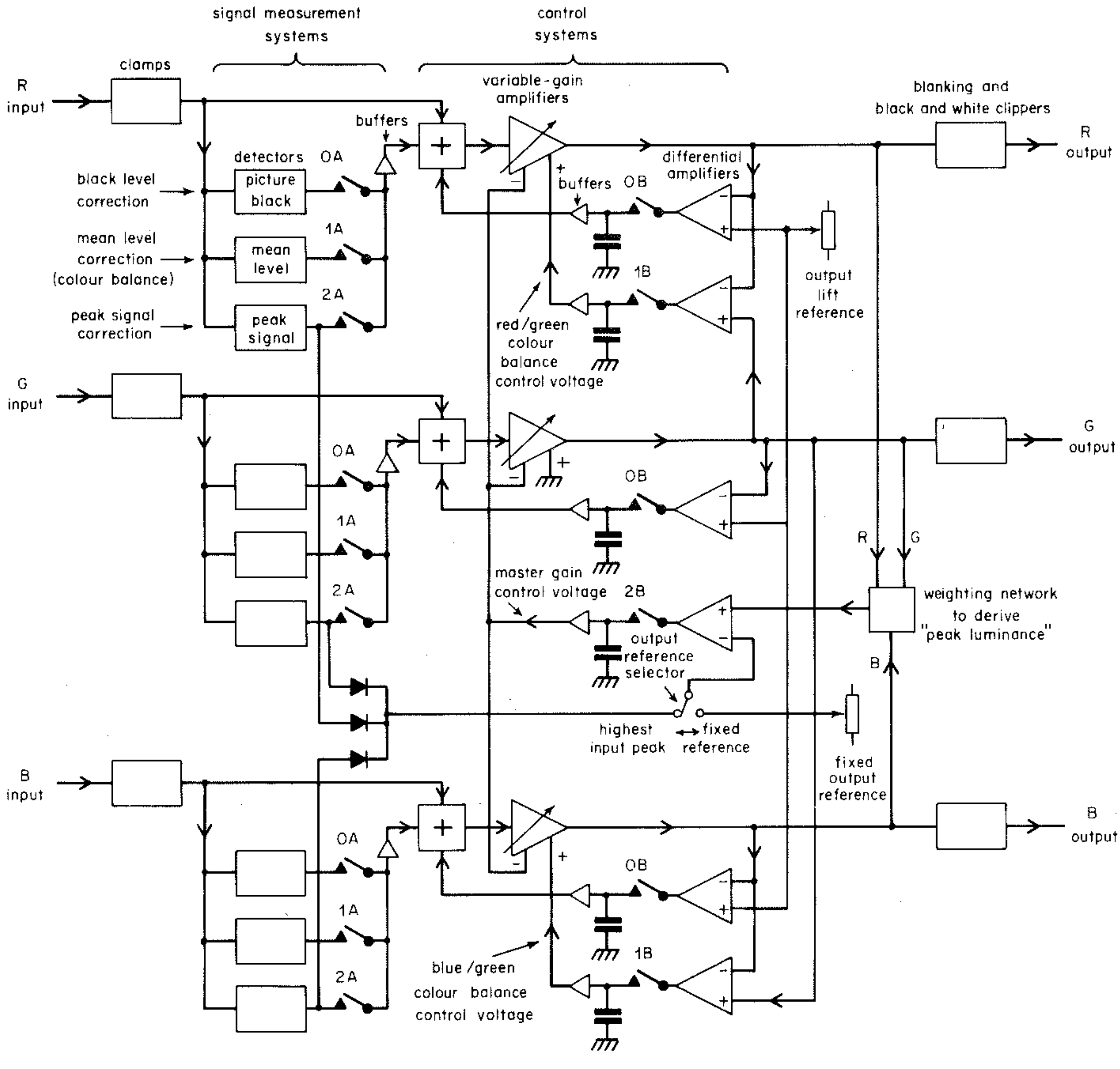

Fig. 3 - Block diagram of three-channel, three-function, control system

tion circuit is produced; this will force the peak signal level at the output to be equal to the reference level. Similarly if the measuring arrangement were to measure the mean level of the input signal, then the gain could be controlled to make the mean level at the output equal to a reference value.

Black-level and gain corrections can be combined around a common signal path by arranging for each correction to be derived during a different time interval, i.e. during different lines in the field-blanking interval.

Fig. 2 shows an arrangement which sets the picture-black and the peak-signal level to their respective reference levels at the output. Because an adjustment of black-level affects the amount of gain required, while a gain adjustment should not affect the black-level, the black-level correction is derived first.

In practice it has been found necessary to ensure that a gain increase raises the black-level slightly (see Section 4.4.). For this reason it is necessary to repeat the correction sequence (black-level, gain) a second time in each field-blanking interval to make the second-order effects insignificant.

The basic principles outlined above can be extended to form a three-channel, three-function, control system as shown in Fig. 3. This is the system used in the complete equipment.

Each channel has an independent black-level correction system which has two minor variations from the circuit shown in Fig. 1(*c*). The signal-measurement-pulses are fed to a buffer amplifier before being added to the video signal, and a common picture-black reference-level is used for all three channels; this reference-level is varied to provide an output-lift control.

Each channel also contains circuits to measure the mean-level and peak-levels of each input signal, and each measurement is added in the form of a pulse to its respective signal during different lines in the field-blanking interval.

Three additional control-loops are used to carry out the colour-balance and gain-correction functions. Two of these loops (associated with the red and blue channels in Fig. 3) are operated during the time that the mean-level measurement pulses are added to the signals, and they are arranged to compare the mean-level measurement pulses at the output of the variable gain amplifiers; red is compared with green to derive a control voltage which varies the red channel gain to achieve equality, and similarly blue is compared with green to derive a blue channel gain-control voltage.

The final control-loop (associated with the green channel in Fig. 3) is operative when peak-signal measurement pulses are added to the signals. At this time a weighted sum of the peak signals at the output is compared with either a fixed reference or the highest input peak-value, and the resulting control-voltage is applied to all three variable-gain amplifiers. The variable-gain amplifiers used have a differential input for the control-voltage and this provides a convenient method of applying two control voltages to one amplifier. The phase of the master-gain feedback-loop is reversed to that the control-voltage can be applied to the negative input of each variable gain amplifier (negative voltage change increases the gain). Then, for the red and blue channels, the colour-balance and gain-correction control-voltages are effectively added.

The timing of the control-loop operations is dealt with in Section 4.2.

With a system arranged as in Fig. 3, it is not practical to disable the control-loops as a means of turning off the correction functions. This is because the gain of the variable-gain amplifier for a given control voltage may vary with temperature; it is therefore not practical to have a pre-set control-voltage to provide a fixed gain of unity. It might at first seem that black-level correction could be prevented by removing the control-voltage. Each loop, however, serves a dual function; in addition to correcting the black-level it stabilises the d.c. operating conditions of the variable gain amplifier. For these reasons the control-loops are left in operation at all times.

The method used is to substitute pulses with fixed reference levels in place of the signal-measurement-pulses as detailed below.

(a) When black-level correction is to be inhibited the measurement pulse representing picture black is not added to the main signal. The effect of this is to set the input blanking level to the output-lift reference-level. Since the output-lift reference-level is normally adjustable, a relay is used to substitute a fixed level which is arranged so that, when the signal is re-blanked, no change in lift level occurs between the input and output signals.

(b) Colour-balance correction is inhibited by adding pulses of the same voltage level to all three channels in place of the independent mean-level measurement pulses. The control loops make these pulses equal at the output and thus all channels have equal gain. The voltage added normally corresponds to a white input signal.

(c) Gain correction is inhibited by assuming that the input signals already have the required peak value. A pulse with a magnitude which corresponds to the normal white-level input is added to each channel in place of the pulse which corresponds to the measured peak value. Under this condition the control-loops maintain a fixed overall-gain.

4.2. Timing of corrections

As mentioned previously each correction function is carried out on a different line in the television field-blanking interval. Black-level correction is carried out before gain correction because black-level correction makes a gain change necessary as a first-order effect, whereas the effects of gain changes upon black-level are only of second order. Even so, with multiple corrections the sequence must be repeated to remove these second-order effects.

With the three-function correction system, shown in Fig. 3, a colour-balance adjustment may well necessitate a gain change, due to the re-arrangement of peak values, whereas the effects of overall gain changes on colour-balance are of second order (these second order effects are caused by instrumental limitations). Colour-balance correction is therefore carried out before overall gain correction. The resulting correction sequence is black, colour-balance, gain and this is carried out twice, the first time to remove gross errors and the second time to remove the second-order effects arising from the first corrections. The two three-line sequences used for the corrections are lines 9, 10, 11 and 13, 14, 15 in the even field and lines 321, 322, 323 and 325, 326, 327 in the odd field. (A binary counter is used to identify the lines, and repeating the sequence after four rather than three lines allows simpler logic to be used.)

The f.e.t. switches which add the signal-measurement-pulses to the signals are operated, for 40 μs in the middle of the active line time, by pulses which are referred to as 'A' pulses. The f.e.t. sample-and-hold switches in the control feedback loops are operated, for the central 32 μs of this period, by pulses which are referred to as 'B' pulses.

In addition, the first pulses in each sequence, which are concerned with black-level correction, are designated '0' (on lines 9 and 13 or lines 321 and 325); the second

TABLE 1

Pulse Designation

	Line Numbers on which pulses occur	40 μs pulse adds signal-measurement pulse to main signal (long pulse)	32 μs pulse closes feedback-loop (short pulse)
Black-level Correction	9 and 13 (even field) 321 and 325 (odd field)	0A	0B
Colour Balance	10 and 14 (even field) 322 and 326 (odd field)	1A	1B
Gain Correction	11 and 15 (even field) 323 and 327 (odd field)	2A	2B

pulses, concerned with colour-balance correction, are designated '1' (lines 10 and 14 or 322 and 326); and the third pulses, concerned with gain correction, are designated '2' (lines 11 and 15 or 323 and 327).

The pulse notation system is summarised in Table 1.

Each type of pulse appears on a separate bus-bar which drives the appropriate f.e.t. switches. The above notations have been used in Fig. 3 alongside all f.e.t. switches to identify the bus-bars from which they are driven.

Signal measurement pulses are added to the signals after every field and so 'A' pulses are produced on every field. On the other hand, if new corrections are only to be applied during alternate field intervals, the 'B' pulses occur on alternate fields only.

It has already been mentioned (Section 4.1.) that, when corrections are not in use, the '0A' pulse is not required and also that the '1A' and '2A' pulses need to be applied to different f.e.t. switches so that reference-pulses rather than signal-measurement-pulses are added to the signals. For this reason, the '1A' and '2A' pulses are each routed by logic gates to appear on one or the other of two bus-bars. In the 'correction-on' mode the pulses are fed to the f.e.t. switches controlling the signal measurement pulses and these are known as '1A' and '2A' pulses as before.

When the 'correction-off' mode is in use the pulses are fed on alternative bus-bars and are known as '1A′' and '2A′'. These bus-bars drive the f.e.t. switches which apply the pulses with fixed reference-levels.

From the above it can be seen that a total of eight different types of f.e.t. drive waveform are required and that each waveform contains a pair of pulses spaced 4 line-periods apart and occurring during specific lines in the field interval. These eight waveforms together with clamp pulses for the input stages are produced from mixed syncs by a printed circuit board referred to as the 'pulse generating board'.

The pulse generating board uses TTL logic to derive the various waveforms, and discrete-component output stages to convert the logic-level pulses to a form suitable for driving the f.e.t. switches (±12V). Circuits are also included to allow remote selection of each of the three modes of operation described in Section 3.1. The circuits have been arranged so that only a single control lead is required; this lead is left open-circuit for no correction (Mode A) terminated with 3·9 KΩ to earth for black-level and gain-correction (Mode B), and connected directly to earth for black-level, gain and colour-balance (Mode C).

A circuit diagram of the complete pulse board (Fig. 5) appears in the Appendix.

4.3. Signal-measurement system

It will be seen from Fig. 3 that there are three types of signal-measurement circuit associated with each channel and that the general arrangement is identical for all three channels. The three measurement systems are constructed on a common printed wiring board. The complete circuit diagram (Fig. 6) appears in the Appendix.

Some aspects of the signal-measurement system which are worthy of special mention are dealt with below.

Peak detectors are used to measure the peak signal level and the signal corresponding to black (the maximum negative excursion of the signal during the active picture interval). The requirement of the peak detectors is that the output at the end of the measurement interval should be equal to the peak positive or negative signal magnitude which occurred (ignoring fast spikes), i.e. the relationship should not contain any scale factor or d.c. offset.

It has been shown by earlier work[4] that a peak detector with a suitable time response can be obtained with the circuit shown in Fig. 4(*a*). The time constant CR is arranged so that peak signals which cover only a very small picture area are not fully measured, and a time constant value of 20 μs was found to provide peak measurements which (allowing for the d.c. offset caused by the diode) coincided with a visual assessment of the waveform. With

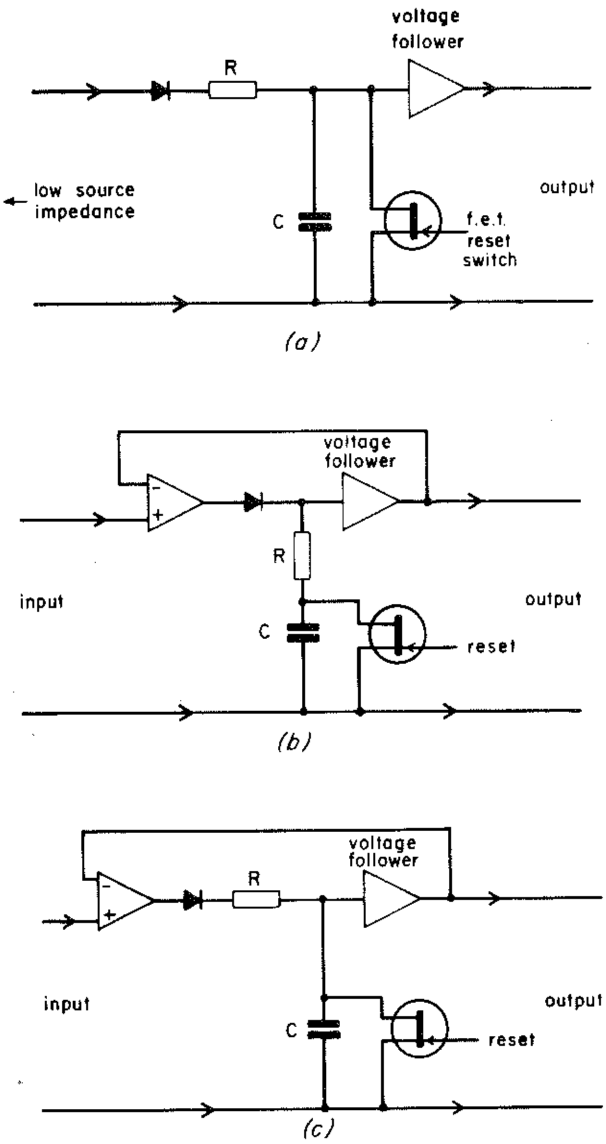

Fig. 4 - Peak detectors

(*a*) basic circuit
(*b*) circuit which removes the d.c. offset caused by the diode
(*c*) switching type circuit which avoids the high frequency stability problems encountered with (*b*)

this time constant the output of the peak detector will be within 1% of the peak signal value after the signal has been present for a total time of 92 μs, i.e. about 0·7% of the field area.

Unfortunately the output from the simple circuit of Fig. 4(*a*) has a large d.c. offset, due to the diode. Early attempts to remove this involved placing the diode in the feedback-loop of an operational amplifier as in Fig. 4(*b*). The buffer amplifier had to be included in the feedback-loop as the operational amplifier would otherwise have severely loaded the capacitor. The arrangement effectively reduced the diode offset-voltage by a factor equal to the gain of the operational amplifier and also had the advantage of not requiring a low source impedance. The circuit was, however, not satisfactory because, with available integrated-circuit amplifiers, it was impossible to obtain a suitable response-time for the detector without losing high-frequency stability. A relatively simple modification to Fig. 4(*b*) produced the final circuit shown in Fig. 4(*c*). Unlike the previous circuits the output of this circuit does not approach the peak-signal value in an exponential manner. Instead, if the signal value exceeds the currently stored peak value, the capacitor is charged at a constant rate until the output voltage equals the input signal value. In this way the operational amplifier and diode operate in a switching mode and the maximum speed of response is obtained. Because the capacitor is now charged linearly, at a rate not dependent on the error between the new peak signal value and the currently-stored peak value, it is necessary to change the time constant to an empirically adjusted value to provide a suitable characteristic. The maximum 'slew rate' of the operational amplifier is such that sharp spikes lasting less than about 500 ns are inherently ignored.

Picture-black detection is achieved by reversing the diode in Fig. 4(*c*) and changing the blanking-level of the input video waveform to a value nearer to white-level than any expected picture black.

The mean-level detector is a straightforward integrator with a gated video-input signal. The gating is used to ensure that any synchronising information which may be present will not affect the measured mean-level. The output voltage is arranged to vary from 10% for no signal input, to 100% for a completely white signal. The reason for the 10% minimum value is that if the input is black-level, the pulse representing the mean-level measurement would otherwise be of zero magnitude and would therefore not be altered (with respect to the black pulse) by variations of gain. This would effectively open circuit the feed-back path and cause the gain-control loops to become unstable. With the 10% minimum value the colour-balance correction does not completely equate low mean levels, i.e. it becomes less precise when there are large dark areas in the scene. In practice this is not a problem because the black-level correction removes most colour casts from this type of scene.

The range of correction is set by limiting the range of the signal measurements as described below:—

(1) If the picture black rises above 50% of the nominal peak signal-input level, the measurement result will be equivalent to the 50% value. This is arranged by re-setting the negative-peak detector so that the result will remain at the limiting value, unless driven more negative by video information. With this constraint the maximum amount of lift correction which can be applied to any channel is thus limited to 50%.

(2) If the input signal-level falls to a low value, an arrangement is used to ensure that the peak-level measurement remains at least 33% (of normal peak input-signal level) above the black-level measurement. This ensures that, even after black-level correction, the maximum gain which can be applied in any channel is three times (about 10 dB).

The above methods for limiting the range of lift and gain correction allow the feedback loops to operate normally at all times. The control loops are in turn designed to apply sufficient correction to cope with the limits set by the measurement system.

4.4. Control system

The control system comprises three identical signal processing paths, one concerned with each of the input channels, and six control feedback-loops which are interconnected between the channels as shown in Fig. 3. The complete system is constructed on one printed board and the circuit diagram appears in the Appendix, where Fig. 7(*a*) shows the signal path for one channel and Fig. 7(*b*) shows all six control loops.

Each signal processing path consists of an adder which adds the measurement pulses and lift-control voltage to the video signal. This is followed by a variable-gain amplifier which is designed using an integrated-circuit modulator. The gain of this device is not linearly related to the control voltage, but the method of use within a feedback-loop makes linearity unnecessary. The current gain of the variable-gain amplifier may be varied from zero to unity. A relatively low value of load resistor is used to avoid high-frequency loss; consequently further amplification is necessary to provide an output voltage large enough for the black-and-white clipper stages which follow. The signal is first 'level-shifted' so that it appears relative to earth, rather than to the 12V supply line, and is then amplified by a conventional feedback 'triple' with a voltage gain of about 7·5 times. To achieve d.c. stability with this relatively high gain, a matched pair of transistors is used for the level-shifting stage and the first stage of the feedback triple. Drift-cancellation techniques have also been used.

Any d.c.-coupled variable-gain amplifier will have a 'hinge-point', i.e. some d.c. value of input signal which does not produce any change at the output when the gain is varied. Ideally, for this application, the hinge-point should be at black-level so that variations of gain will not affect the black-level at the output. It was, however, found that the hinge-point moved slightly between low and high gain settings and that the manner in which it moved depended on the integrated-circuit manufacturing tolerances and could not be predicted.

It is important that a gain increase should not make any part of the video waveform more negative, otherwise the phase of the gain feedback-loops would effectively be reversed and hunting would occur (this would be seen as pronounced flicker in the output picture). It is therefore arranged that an increase in gain always slightly raises the black-level of the output signal. To achieve the required conditions a d.c.-balance control is provided; this operates by altering the bais conditions of the integrated-circuit modulator.

Each control feedback-loop has a comparator which compares the voltage levels in the appropriate signal paths at all times. When the signal measurement pulses are present the comparison is valid and the output of the comparator is connected to the sample-and-hold capacitor by a f.e.t. switch. Each comparator is an integrated-circuit, high-gain, high-speed operational amplifier with its output voltage swing limited to ±5V. This limit is set so as to ensure that the f.e.t. gate-driving voltage is always sufficiently greater than the control voltage, thus providing reliable switching.

The sample time is 32 μs and, if the holding capacitor is to be charged to within 1% during this time, the charge time constant must be about 7 μs. On the other hand, when new corrections are applied only on alternate fields, the hold time is 40 ms and to achieve less than 1% droop during this interval a discharge time constant of 4s is required. The output resistance of the comparator, and the 'on' resistance of the f.e.t. switch, set the maximum value of capacitance which could be used to about 0·1 μF. It follows that, for a discharge time-constant of 4s, the voltage on the capacitor must be fed to a buffer amplifier with a very high input impedance and a very low input bias-current. A suitable integrated-circuit voltage-follower was found and this has been used in the equipment. Field-effect transistors connected as source followers could have been used but allowance would then have had to be made for the resulting relatively large d.c.-offset voltage.

4.5. Miscellaneous instrumentation

The circuit diagram for the input amplifier and feedback-clamp is shown in the Appendix, Fig. 8. It consists of a conventional feedback triple with a voltage gain of three, around which a feedback-clamp is connected. The clamp is designed to place the blanking-level at the output of the amplifier at zero volts to within 0·1% of the nominal peak-signal value. Clamp pulses are generated by the pulse generating board.

The output processing consists of black-level and white-level clippers with facilities for re-blanking the signal. These are followed by an output amplifier. The circuit appears in the Appendix (Fig. 9).

5. Operational field trials

5.1. General

An automatic Tarif unit of the type described in this report has been in use for News film transmissions for several months. The unit was installed in a camera-tube colour telecine channel and preceded the existing manual Tarif unit. Apart from some early teething troubles, which resulted in minor modifications, the equipment has not required any alignment or maintenance.

Because its use has been confined to one telecine channel the aggregate effect on the total of news film broadcast has not been great, but of the news film which has been reproduced on that channel about one third of the items have benefited by some degree of automatic correction. In particular the black-level correction has been found very useful for removing low-light colour-casts and fogging effects such as may be caused by film processing errors,

whilst at the same time hardly ever causing significant objectionable effects.

Operational staff from Television News made the following comments after the first six months of field trials:

(i) Since the operation of the device is based (necessarily) on stochastic assumptions about the nature of the average scene, one would expect it to be most satisfactory on pictures with random colorimetric content, and this has been confirmed by experience. Thus, crowd scenes are generally handled well, and with such material widely ranging colour casts are eliminated with a speed and accuracy a manual Tarif cannot match.

(ii) Compilation stories in which original film is intercut with multi-generation library prints also benefit greatly from automatic control. This category includes obituary material, recapitulations, News Review, headlines etc.

(iii) Other material for which automatic Tarif is suitable, is the repetitive shots of people entering shaded interiors from bright sunlight, and the often very bad American 'Film-Off-Tape' items.

(iv) Stories of a static nature, such as non-overlaid reports-to-camera and, most especially, close-up interviews, are in a very different category, and it is wise not to apply auto-correction, (particularly in the integrate to grey colour-balance mode) to such items unless a rehearsal is possible. For example, a human face can turn bright cyan at the passing of a red bus. Auburn hair is rendered black if it happens to be the darkest significant area, and this in turn reacts on the rendition of face tones.

(v) As expected, film of really good quality is degraded by auto-correction.

(vi) There is in the device a consistent tendency to reproduce neutral highlights as coloured, and to generate a generally cold colour-balance. Attempts carried out (with the co-operation of Research Department) to improve the balance by biasing the gain-control amplifiers so that the picture integrated toward pink rather than grey caused unfavourable effects on the highlight rendition. The pictures produced by the device are of course immune to any but gross maladjustments of the telecine grey scale.

(vii) The high incidence of unrehearsed items, together with the idiosyncrasies inherent in the device have led to its being almost invariably used in conjunction with a manual Tarif (which follows it). Records indicate that its use in the 'black-level and gain' and 'black-level gain and colour-balance' modes have been roughly in the proportion 2:3, but it is not thought that its indiscriminate use in either mode would be satisfactory and certainly not without the backing of a manual Tarif. Used with discretion, however, it is undoubtedly an extremely valuable adjunct to existing control.

5.2. Additional field trials

A second unit has completed several months of field trials in conjunction with twin-lens flying-spot telecine machines at Television Centre. During this time it has been used to correct film for current affairs programmes, since such film has a similar nature to news film. It has also been used on some old Feature Films of very poor colour-quality and has proved useful for dealing with programmes in which monochrome film is intercut with colour film.

6. Conclusions

The equipment described in this report was developed in order to be able to carry out comprehensive field trials of a previously envisaged method of colour correction. For this reason it was designed as a portable add-on-unit which can be used at the output of a telecine channel or any other source that produces colour-separation signals.

Two units have been on field trials for several months and these have shown that the unit provides a useful addition to existing control facilities.

7. Acknowledgements

Thanks are due to the staff of Television News for their co-operation in carrying out field trials and for their useful comments which resulted in some improvements to the equipment described.

In particular I would like to thank K.A. Clark, S.Tel.E.News Telecine for his very detailed comments which appear in Section 5.

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APPENDIX

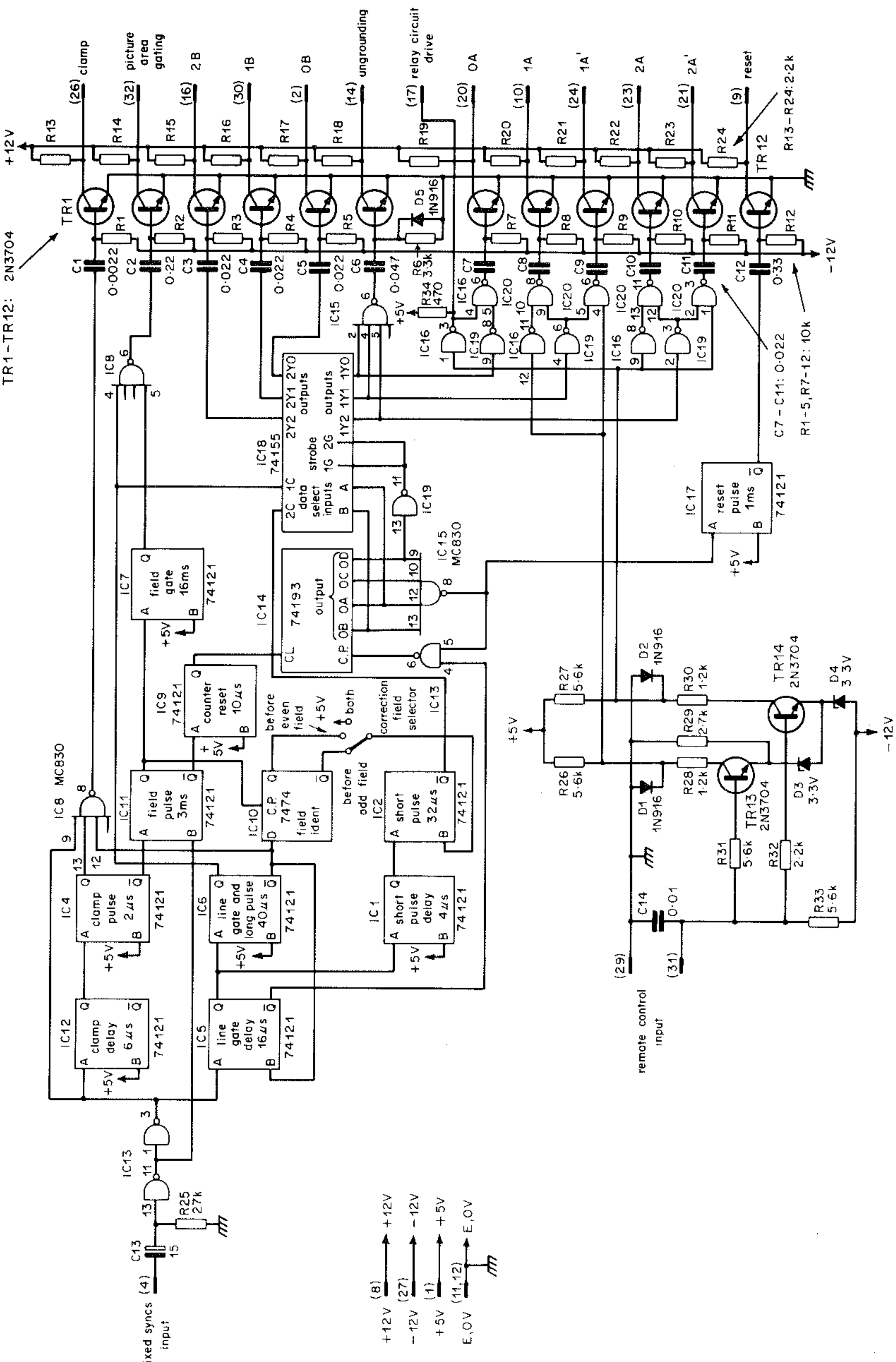
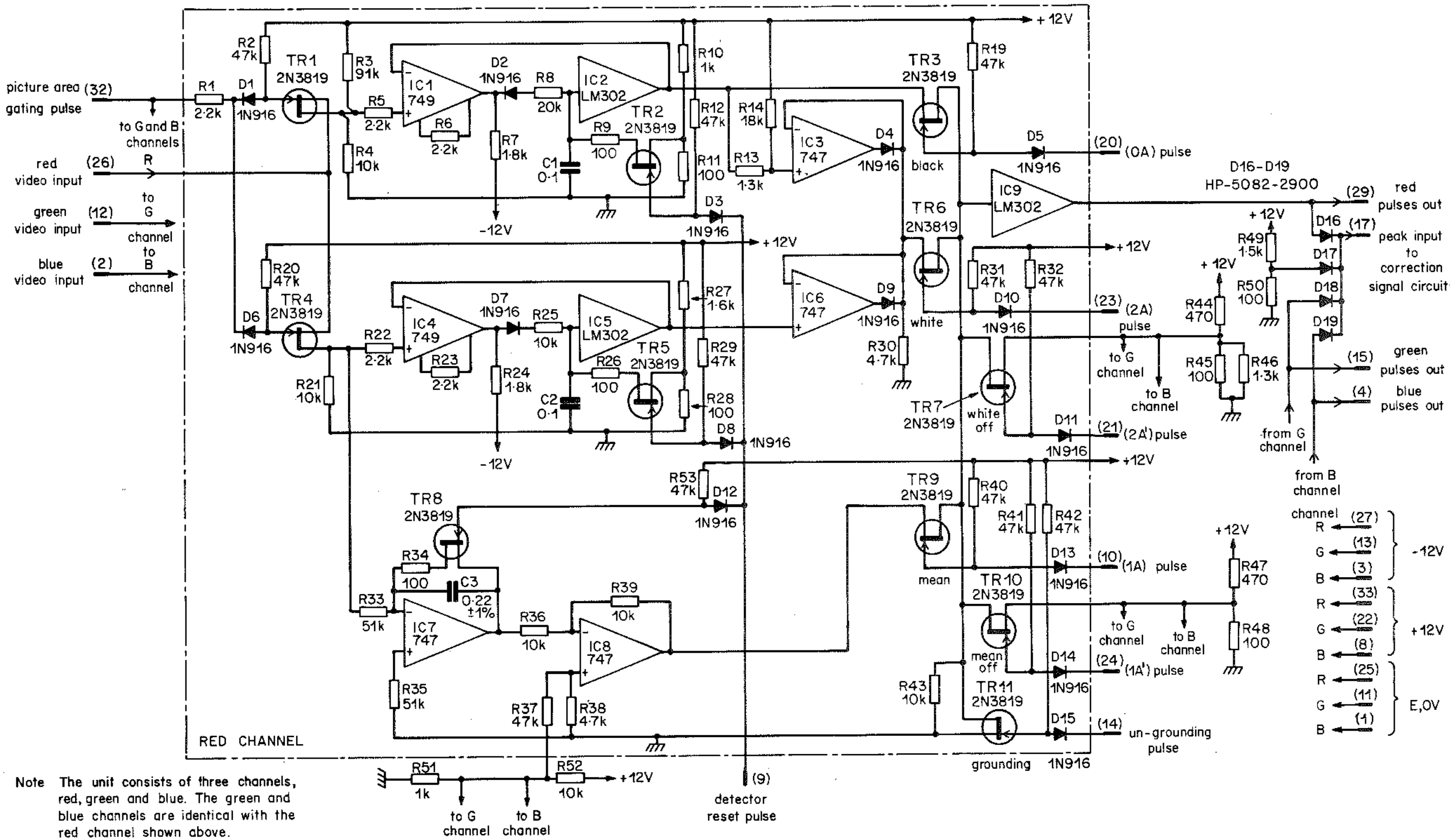
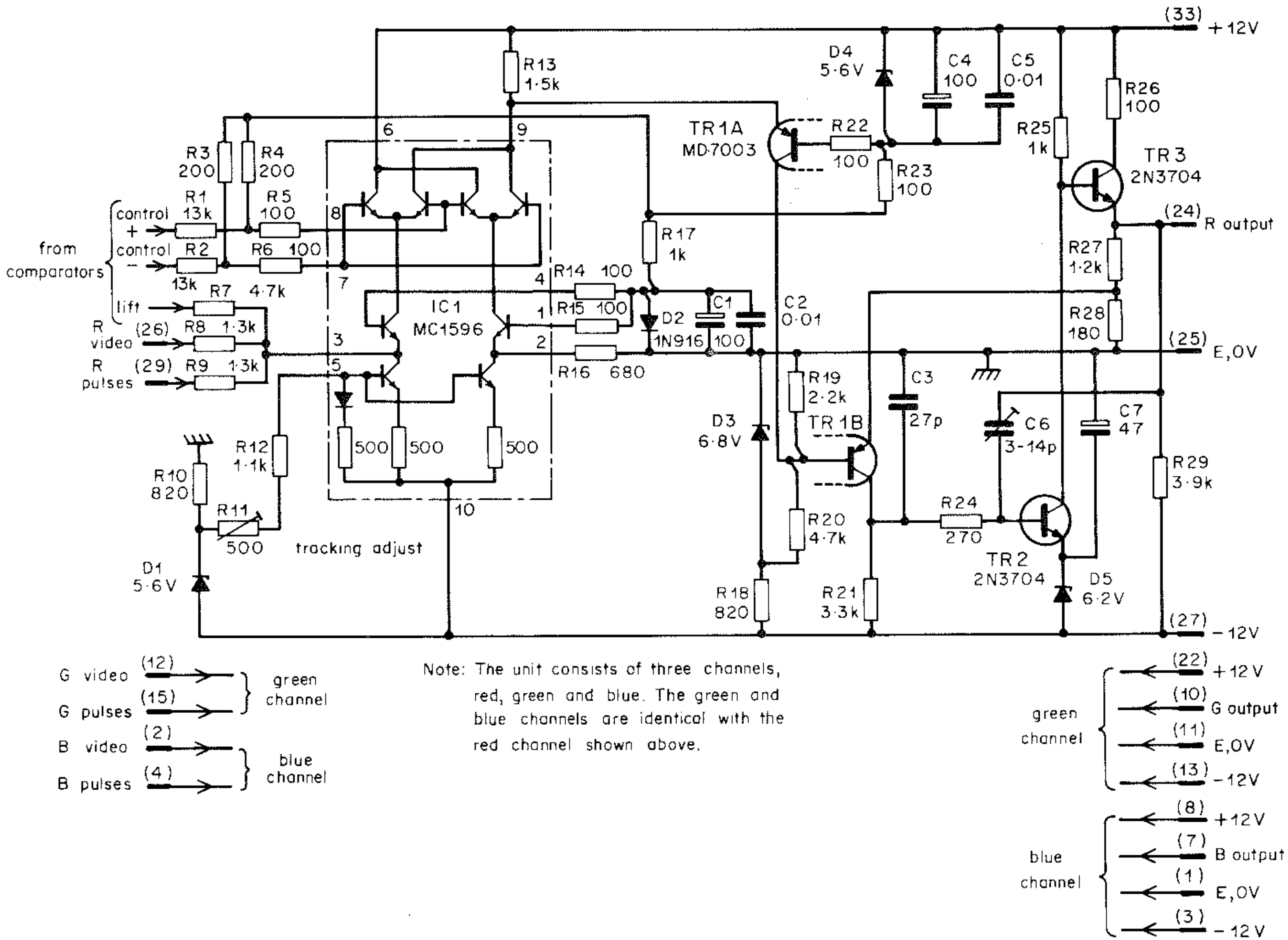


Fig. 5 - Circuit diagram of pulse generating board



Note The unit consists of three channels, red, green and blue. The green and blue channels are identical with the red channel shown above.

Fig. 6 - Circuit diagram of signal-measurement system



Note: The unit consists of three channels, red, green and blue. The green and blue channels are identical with the red channel shown above.

Fig. 7 - Circuit diagram of control system

(*a*) signal path

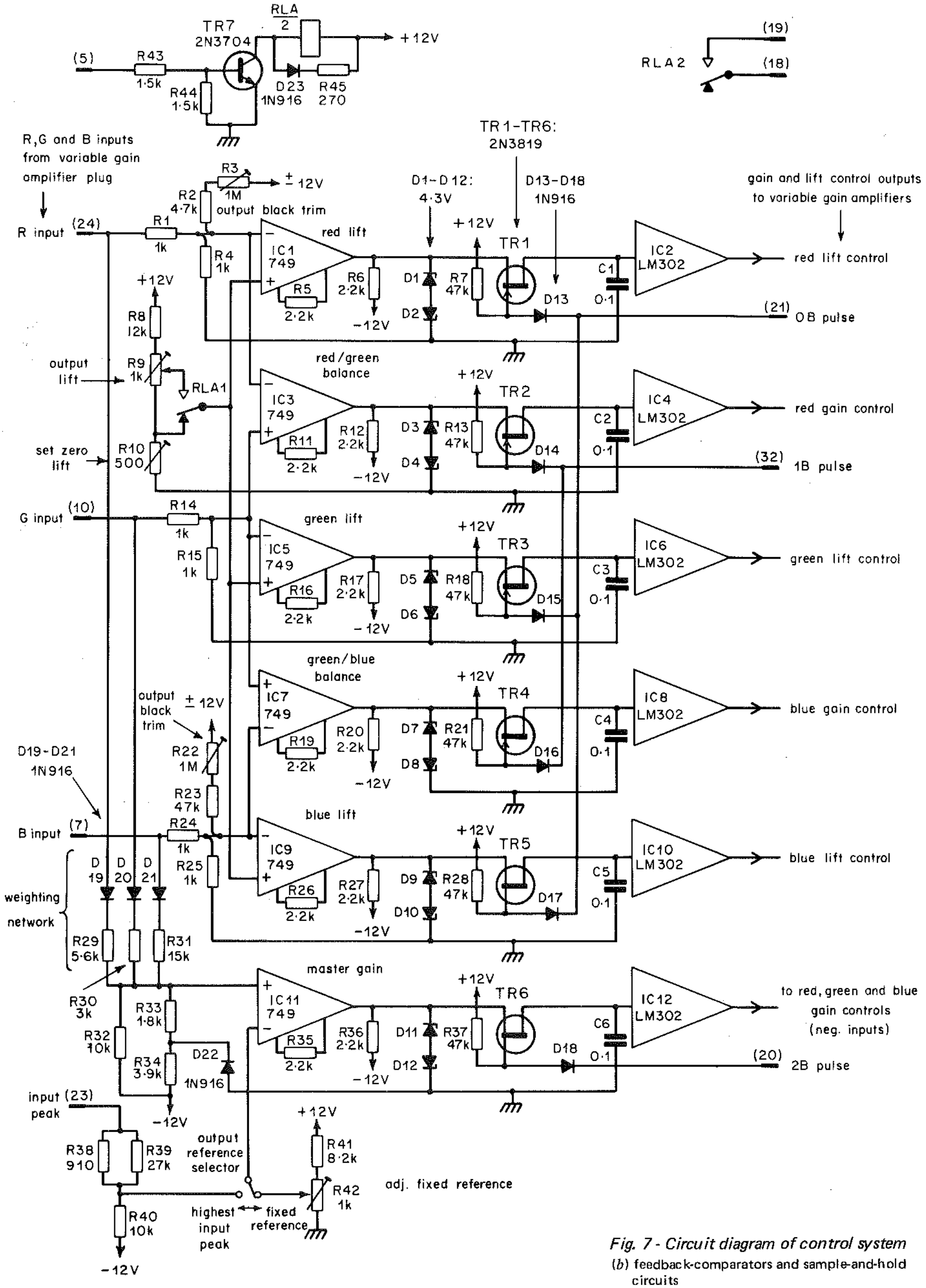


Fig. 7 - Circuit diagram of control system
(*b*) feedback-comparators and sample-and-hold circuits

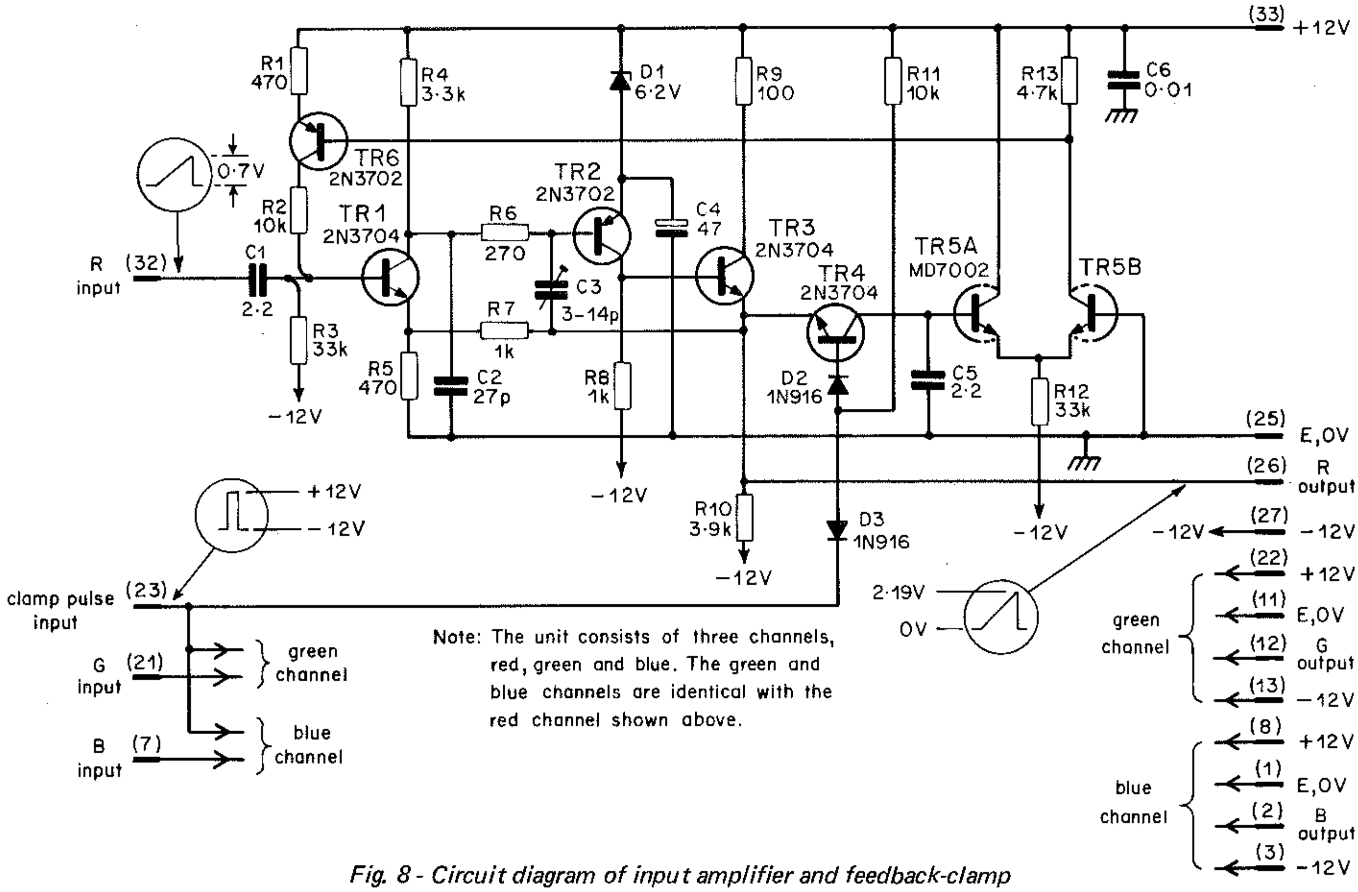


Fig. 8 - Circuit diagram of input amplifier and feedback-clamp

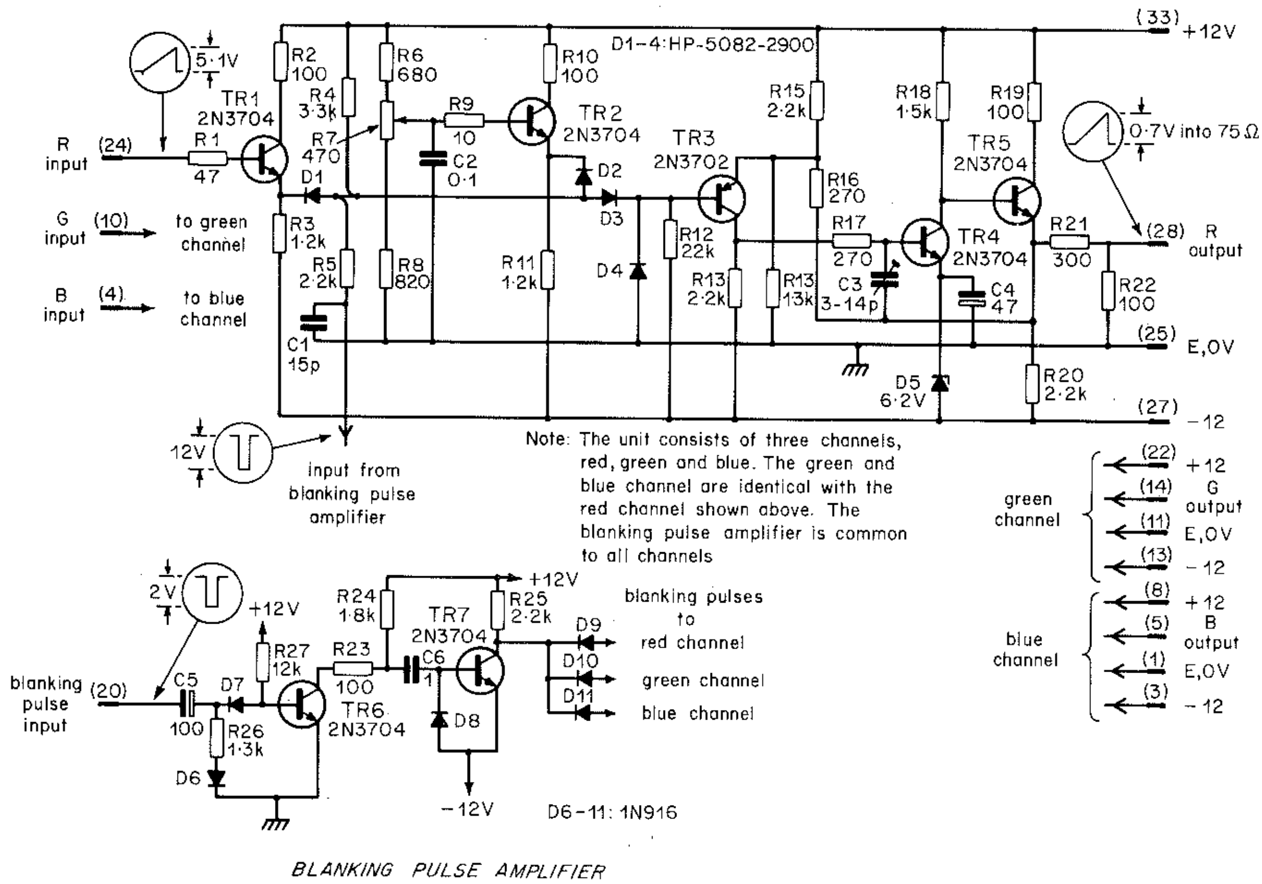


Fig. 9 - Circuit diagram of output processing

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